

Remarks

This Preliminary Amendment cancels, without prejudice, claims 1-15 in the underlying PCT Application Number PCT/FR04/003141 and adds new claims 16-30. The new claims, inter alia, conform the claims to United States Patent and Trademark Office rules and do not add any new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/FR04/003141 includes an International Search Report, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

Applicants assert that the subject matter of the present invention is new, non-obvious and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
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TERMINAL END-PIECE FOR A FUEL ASSEMBLY HAVING AN ARRANGEMENT
FOR MAINTAINING THE ENDS OF THE RODS AND CORRESPONDING
ASSEMBLY

~~Terminal end piece for a fuel assembly having means for
maintaining the ends of the rods and corresponding
assembly~~

FIELD OF THE INVENTION

The present invention relates to a terminal end-piece for a nuclear reactor fuel assembly, the assembly comprising fuel rods and a skeleton for supporting the fuel rods, the fuel rods extending in a longitudinal direction and being arranged at the nodes of a substantially regular network, the support skeleton comprising two terminal end-pieces and elements for connecting the terminal end-pieces, the fuel rods being arranged longitudinally between the terminal end-pieces.

The invention is used in particular for constructing bottom end-pieces of fuel assemblies for ~~pressurised~~pressurized water nuclear reactors (PWR).

BACKGROUND INFORMATION

EP-537 044 describes a bottom end-piece for such an assembly. That end-piece comprises a horizontal wall which is provided with feet for support on the lower plate of a nuclear reactor core. The elements for connecting the bottom end-piece to the top end-piece are constituted by guide tubes. Those guide tubes are fixed to the horizontal wall of the end-piece. The horizontal wall comprises reinforcement ribs under the lower surface thereof. In each zone of the horizontal wall delimited between the reinforcement ribs, holes for the passage of coolant water are provided so that the horizontal wall constitutes an anti-debris filter.

The coolant water flows in the core of the reactor vertically in an upward direction. More precisely, the water is introduced into the core through the lower core plate,

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then passes through the bottom end-piece by way of the above-mentioned holes before coming into contact with the outer surfaces of the fuel rods.

5 The water flows in the core at a very high ascending rate.

It has been found, during operation of the core, that the fuel rods, and in particular the lower ends thereof, were subjected to vibrations which are liable to damage them.

10

In greater detail, phenomena involving friction or "fretting" are liable to occur in particular between the lower grid of the support skeleton and the outer claddings of the fuel rods.

15

These friction phenomena may lead to damage to outer claddings which may bring about a release of fission gas or product in the water of the primary circuit.

20

SUMMARY

An objectobjective of the invention is to overcome this problem by limiting the vibrations of the fuel rods of assemblies for a nuclear reactor.

25 To that end, the invention relates to a terminal end-piece for a nuclear reactor fuel assembly, the assembly comprising fuel rods and a skeleton for supporting the fuel rods, the fuel rods extending in a longitudinal direction and being arranged at the nodes of a substantially regular network,

30 the support skeleton comprising two terminal end-pieces and elements for connecting the terminal end-pieces, the fuel rods being arranged longitudinally between the terminal end-pieces, characterised in that it comprises meansan arrangement for laterally maintaining the adjacent

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longitudinal ends of substantially all the fuel rods, which maintenance ~~means~~arrangement are arranged at nodes of the substantially regular network.

- 5 According to specific embodiments, the end-piece may comprise one or more of the following features, taken in isolation or according to any technically possible combination:
 - 10 - the maintenance ~~means~~arrangement comprise housings for receiving the adjacent longitudinal ends of the fuel rods,
 - the maintenance ~~means~~constitute~~means~~arrangement constitutes an arrangement for longitudinally securing the adjacent longitudinal ends of the fuel rods relative to the terminal end-piece,
 - 15 - the end-piece comprises two components for clamping between them the adjacent longitudinal ends of the fuel rods,
 - one of the components constitutes an anti-debris filter,
 - 20 - the longitudinal securing ~~means~~comprisearrangement comprises projections, to which rings of the adjacent longitudinal ends of the fuel rods are intended to be fitted,
 - 25 - the longitudinal securing ~~means~~comprisearrangement comprises screws ~~which~~that are intended to be engaged in the adjacent longitudinal ends of the fuel rods,
 - the longitudinal securing ~~means~~are~~means~~forsecuring ~~by~~meansofarrangement secures by snap-fitting,
 - 30 - the end-piece constitutes a bottom end-piece and the adjacent longitudinal ends are the lower ends of the fuel rods and
 - the end-piece comprises feet for support on a lower plate of the core of the nuclear reactor.

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The invention further relates to a fuel assembly for a nuclear reactor, the assembly comprising fuel rods and a skeleton for supporting the fuel rods, the fuel rods
5 extending in a longitudinal direction and being arranged at the nodes of a substantially regular network, the support skeleton comprising two terminal end-pieces and elements for connecting the terminal end-pieces, the fuel rods being arranged longitudinally between the terminal end-pieces,
10 characterised in that at least one end-piece is an end-piece as defined above.

According to specific embodiments, the assembly may comprise one or more of the following features, taken in isolation or
15 according to any technically possible combination:

- the maintenance means constitute ~~means~~an arrangement for longitudinally securing the adjacent longitudinal ends of the fuel rods relative to the terminal end-piece,
- 20 - the maintenance ~~means~~constitute ~~means~~arrangement constitutes an arrangement for longitudinally securing the adjacent longitudinal ends of the fuel rods relative to the terminal end-piece,
- the end-piece comprises two components which clamp
25 between them the adjacent longitudinal ends of the fuel rods,
- the longitudinal securing ~~means~~comprisearrangement comprises projections ~~which~~that are provided on the end-piece and rings which are provided at the adjacent
- 30 longitudinal ends of the fuel rods and which are fitted to those projections,
- the rings comprise relief portions for abutment against one of the components,

- the adjacent longitudinal ends of the fuel rods comprise widened feet which are clamped between the two components,
- the adjacent longitudinal ends of the fuel rods are expansion-rolled on the end-piece,
- the longitudinal securing means ~~comprise arrangement comprises~~ screws which abut the end-piece and which are engaged in the adjacent longitudinal ends of the fuel rods, and

10 - the longitudinal securing means ~~are means for securing by means of~~ is by snap-fitting.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from a reading of
15 the following description given purely by way of example and with reference to the appended drawings, ~~in which:~~.

—Figure 1 is a schematic side view of a fuel assembly according to the prior art.

20 —Figure 2 is a schematic top view showing the distribution of the fuel rods in the assembly of Figure 1.

—Figure 3 is a schematic bottom view of the bottom end-piece of a fuel assembly according to a first variant of a first embodiment of the invention.

—Figure 4 is a schematic perspective view of the end-piece of Figure 3.

30 —Figure 5 is a schematic partial, perspective, exploded view showing the connection of the bottom end-piece of Figure 3 to the fuel rods and the guide tubes.

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—Figure 6 is a partial, schematic view, sectioned along the plane VI-VI of Figure 5, illustrating the connection between the bottom end-piece, the guide tubes and the fuel rods—.

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—Figure 7 is a partial, schematic top view illustrating the connection of a foot to the remainder of the bottom end-piece of Figure 3,3.

10 —Figure 8 is a schematic, partial, perspective view illustrating a second variant of the first embodiment of the invention—.

15 —Figure 9 is a schematic, partially sectioned side view illustrating a first variant of a bottom end-piece according to a second embodiment of the invention—and.

20 —Figures 10 to 13 are views similar to Figure 9 illustrating other variants of the second embodiment of the invention.

DETAILED DESCRIPTION

In order to illustrate the context of the invention, Figure 1 schematically illustrates a nuclear fuel assembly 1 for a pressurised water reactor. Therefore, the water fulfils in that case a coolant and moderating function, ~~that is to say for example~~, slowing down the neutrons produced by the nuclear fuel.

30 The assembly 1 extends vertically and in a rectilinear manner in a longitudinal direction A.

Conventionally, the assembly 1 principally comprises nuclear fuel rods 3 and a structure or skeleton 5 for supporting the rods 3.

5 The support skeleton 5 conventionally comprises:

- a bottom end-piece 7 and a top end-piece 9 ~~which~~that are arranged at the longitudinal ends of the assembly 1,
- guide tubes 11 ~~which~~that are intended to receive the rods of an assembly ~~(not illustrated)~~ for controlling and stopping the nuclear reactor and
- grids 13 for maintaining the rods 3.

15 The end-pieces 7 and 9 are fixed to the longitudinal ends of the guide tubes 11.

The rods 3 extend vertically between the end-pieces 7 and 9. The rods 3 are arranged at the nodes of a substantially regular network having a square base, where they are maintained by the grids 13. Some of the nodes of the network are occupied by the guide tubes 11 and optionally by an instrumentation tube 14 which is visible at the ~~entre~~center of Figure 2. In Figure 2, the rods 3 are shown with dashed lines, the guide tubes 11 are shown with solid lines and the instrumentation tube 14 is shown using a solid black circle.

30 The grids 13 conventionally comprise sets of intersecting plates 15 which together delimit cells which are centred on the nodes of the regular network. Most of the cells are intended to receive a fuel rod 3. 24 cells each receive a guide tube 11 and the central cell receives the instrumentation tube 14.

In the example of Figures 1 and 2, the maintenance grids 13 comprise 17 cells per side and the regular network comprises the same number of nodes per side.

5 In other variants the number of cells and nodes per side may be different, for example, in the order of 14 x 14 or 15 x 15.

Each rod 3 conventionally comprises an outer cladding 17
10 ~~which~~that is closed by a lower plug 19 and an upper plug 21 and ~~which~~that contains the nuclear fuel. These are, for example, stacked pellets of fuel, the pellets being supported on the lower plug 19.

15 A helical maintenance spring (~~not illustrated~~)—may be arranged in the cladding 17 between the upper pellet and the upper plug 21.

Figures 3 to 7 illustrate a bottom end-piece 7 according to
20 the invention ~~which~~that may be fitted to an assembly 1 as described with reference to Figures 1 and 2. Preferably, ~~the~~The maintenance grids 13 are grids such as those described in documents US-6 542 567 and EP-925 589. In some variants, the end-piece 7 may further be fitted to
25 assemblies which are different from that described above and/or which comprise different maintenance grids.

The end-piece 7 comprises a horizontal wall 23 and feet 25 which extend the wall 23 downwards in order to be supported
30 on the lower plate of the core of the reactor.

The wall 23 is generally of planar parallelepipedal form and the feet 25 are each arranged at a corner of the wall 23.

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The wall 23 comprises a lower member 29 and an upper plate 31 which covers the member 29.

The lower member 29 comprises a plurality of units 33
5 ~~which~~that are arranged at the nodes of the same network as
the fuel rods 3, the guide tubes 11 and the instrumentation
tube 14.

In this manner, as is visible in Figure 3, the member 29
10 comprises 17 x 17 units 33 of cylindrical shape.

Therefore, each unit 33 is located longitudinally below a
fuel rod 3, a guide tube 11 or the instrumentation tube 14,
if the assembly 1 comprises them.

15 The units 33 are connected to each other by reinforcement
ribs 37 which form a grid-like square around the lower
member 29.

20 The units 33 ~~which~~that are arranged under the fuel rods 3,
~~that is to say, wherein~~ most of the units 33, have a diameter
substantially corresponding to the outer diameter of the
rods 3 and are extended downwards by noses 39. Those noses
39 are substantially of ogive-like forms converging
25 downwards. Those noses 39 are integrally formed with the
respective units 33.

As ~~can be seen~~ illustrated in Figures 3 and 6, the units 33
arranged below the guide tubes 11 and the instrumentation
30 tube 14 do not comprise integrated noses 39, but are instead
perforated by vertical holes 41. For each unit 33 arranged
under a guide tube 11, the hole 41 is a hole for receiving
the shank of a screw 43 for fixing the end-piece 7 to the
relevant guide tube 11. It will be appreciated that the head

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45 of the screw 43 is substantially of ogive-like form and also constitutes a nose 39 which is arranged under the respective unit 33. It should be noted that the screws 43 have not been illustrated in Figure 3.

5

The hole 41 of the central unit 33 which is arranged under the instrumentation tube 14 is itself left free in order to allow the introduction of the probe of the instrumentation tube 14.

10

In this manner, the lower member 29 of the end-piece 7 has a network of noses 39 that is similar to that of the fuel rods 3 and the guide tubes 11.

15

That network is interrupted only in the region of the instrumentation tube 14. In some variants, the network may also be interrupted locally in the region of that tube 14 in a more significant manner.

20

In those variants, however, the majority of the rods 3 remain arranged above noses 39.

25

The units 33 ~~which that~~ are arranged below the fuel rods 3 further have blind holes 47 ~~which that~~ open in the upper surface of the lower member 29. Those holes 47 have upper portions 49 which diverge upwards.

30

As illustrated in Figures 5 and 6, the upper plate 31 comprises rings 51 ~~which that~~ are arranged at the nodes of the same substantially regular network as the units 33. The internal passages 52 of the rings 51 arranged below the fuel rods 3 have upper portions 53 ~~which that~~ diverge upwards and substantially cylindrical lower portions 55 ~~which that~~ are arranged in a continuation of the upper divergent portions

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49 of the blind holes 47. The outer diameter of those rings 51 is substantially equal to that of the rods 3.

The internal passages 52 of the rings 51 arranged under the 5 guide tubes 11 and the instrumentation tube 14 are, for example, of cylindrical form. The outer diameter of those rings 51 is substantially equal to that of the guide tubes 11 and the instrumentation tube 14.

10 The rings 51 are connected to each other by reinforcement ribs 57 ~~which~~that are arranged, for example, in grid-like form similar to that of the ribs 37 of the lower member 29.

When the upper plate 31 covers the lower member 29 of the 15 end-piece 7, as ~~can be seen~~illustrated in Figures 5 and 6, the ribs 57 are arranged above the ribs 37 of the member 29, the rings 51 are arranged above the units 33. Therefore, there is longitudinal continuity between the member 29 and the plate 31.

20 Plates 59, which are finer than the ribs 57, extend between the rings 51 and the ribs 57 in order to delimit, in the plate 31, holes 61 for the passage and filtration of the coolant water. In the example illustrated, the plates 59 are 25 arranged in grid-like form.

In this manner, the upper plate 31 forms an anti-debris filter.

30 As illustrated in greater detail in Figures 5 and 6, the shanks 62 of the screws 43 for fixing the guide tubes 11 extend through the corresponding holes 41 and are engaged in lower plugs 63 ~~which~~that are fixedly joined to the guide tubes 11. The plugs 63 are then supported on the upper plate

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31 and the heads 45 of the screws 43 abut under the lower member 29.

The upper plate 31 and the lower member 29 adjoin each other
5 and the end-piece 7 is fixedly joined to the remainder of the support skeleton 5.

As is visible in Figure 7, the feet 25 have, for example, been fixed to the corners of the lower member 29 by means of
10 fixing screws 65.

It will be appreciated that, in Figure 7, the unit network 33 has been illustrated only partially and the structure thereof has not been shown in detail.

15 The passages 52 of the rings 51 arranged under the fuel rods 3 and the blind holes 47 of the units 33 arranged below form housings 67 for receiving the lower plugs 19 of the fuel rods 3.

20 In the example illustrated in Figures 3 to 7, the lower plugs 19 are supported on the upper divergent portions 53 of those passages 67 via regions of complementary shape. The rods 3 are thus all maintained laterally via their lower
25 ends relative to the bottom end-piece 7. The upper ends of the rods 3 are, for example, free as in the prior art and are not maintained by the top end-piece 9.

30 The presence of the noses 39, ~~which~~that are positioned in a continuation of the rods 3 and the guide tubes 11, allows the flow paths to be orientated substantially vertically along the lower ends of the rods 3 and therefore the lateral rates of flow of the water to be reduced.

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The vibrations of the lower ends of the rods 3 are thereby reduced during operation of the reactor.

The risks of vibration of the rods 3 are still further
5 reduced because the lower ends of the rods 3 are laterally maintained by the end-piece 7 itself. In this manner, the vibrations of the rods 3 are limited up to such a point that it is possible to dispense with the lower maintenance grid 13.

10

The risks of damage ~~owing~~^{due} to fretting of the claddings 17 of the fuel rods 3 are therefore limited.

It will be appreciated that the end-piece 7 further has good
15 transparency with respect to the flow of water and therefore does not bring about any great pressure drop.

In general terms, forms other than ogive-like forms may be envisaged for the noses 39 for longitudinally orientating
20 the flow in the region of the lower ends of the rods 3.

Thus, these may be in particular forms ~~which~~^{that} converge towards the bottom, such as conical forms.

25 Furthermore, the density of the noses 39 may be less than in the example described above, so long as the majority of the rods 3 are arranged above noses 39.

Typically, the bottom end-piece 7 may be constructed from
30 stainless steel or a zirconium alloy.

It can be constructed by any conventional method.

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In this manner, the member 29 and the plate 31 can be constructed either by moulding or by a method using abrasive jets of water at a very high pressure (several thousands of bar), the water being able to be loaded with abrasive
5 particles.

As illustrated by the variant of Figure 8, the horizontal wall 23 of the bottom end-piece 7 is not necessarily constituted by two portions.

10 Thus, in that variant, the anti-debris filter is integrated in the member 29, ~~that is to say that~~ for example the plates 59 extend between the reinforcement ribs 37.

15 In the variantexemplary embodiment of Figure 8, it will also be appreciated that the feet 25 are, similarly to the plates 59, integrally formed with the member 29.

The bottom end-piece 7 is constructed in one piece.

20 It will also be appreciated that noses 39 arranged in a network substantially corresponding to that of the rods 3 can be used irrespective of the presence on the end-piece 7 of means for maintaining the lower ends of the rods 3.

25 Conversely, the maintenance of the rods 3 by the bottom end-piece 7 may be more extensive and may include longitudinal securing, as illustrated by the second embodiment of the invention.

30 The first variant of this embodiment, illustrated in Figure 9, differs from that of Figures 1 to 7 principally in that the units 33 arranged longitudinally below the fuel rods 3

are extended upwards by projections 71 ~~which~~that are bordered by circular grooves 73.

The lower plugs 19 of the rods 3 are extended downwards by
5 substantially cylindrical rings 75. Those rings 75 are split
in order to have resiliently deformable tongues 77.

Each ring 75 is deformed in order to have a curved
protuberance constituting a circular enlargement 79.

10 The inner diameter of the ring 75 is slightly smaller than
the outer diameter of the projections 71.

In order to assemble the fuel rods 3 at the bottom end-piece
15 7, it is necessary to proceed as illustrated by the left-
hand portion of Figure 9.

The upper plate 31 has been fitted on the fuel rods 3
beforehand by passing the upper ends of the fuel rods 3 into
20 the internal passages 52 of the rings 51.

Subsequently, the rings 75 are fitted on the projections 71,
as indicated by the arrow 81 in the left-hand portion of
Figure 9.

25 During that fitting operation, the tongues 77 are slightly
resiliently deformed in a laterally outward direction.

Next, the upper plate 31 is lowered until it moves into
30 abutment against the lower member 29, as illustrated by the
right-hand portion of Figure 9.

Lower portions 83 of the passages 52 of the rings 51 then
move into abutment against the enlargement 79. Those lower

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portions 83 are, for example, of forms which diverge towards the bottom.

Fixing the bottom end-piece 7 to the guide tubes 11 by means
5 of the screws 43 described above completes the assembly of the support skeleton 5.

The upper plate 31 is then maintained in a state longitudinally abutting the lower member 29 and thereby
10 longitudinally clamps the lower ends of the rods 3 against the member 29 by means of the enlargements 79.

All the fuel rods 3 are then secured longitudinally relative to the bottom end-piece 7, thereby bringing about lateral
15 securing of the rods 3 relative to the end-piece 7, which further reduces the risks of vibrations of the fuel rods 3 and damage owing to fretting.

Figure 10 illustrates a second variant of this embodiment.
20 In this variant, the rings 75 have outer diameters which are reduced further, and are therefore smaller than the outer diameter of the claddings 17 of the fuel rods 3. The rings 75 are connected by shoulders 85 to the lateral surfaces of
25 the lower plugs 19. The central passages 52 of the rings 51 have, in addition to the lower diverging portion 83, an upper portion 87 which diverges towards the top.

The outer diameter of the projections 71 is reduced further
30 than in the first variant of Figure 9.

In order to assemble the fuel rods 3 at the bottom end-piece 7, first the rings 75 are introduced in the passages 52 of the rings 51 of the grid 31, as indicated by the arrow 88 at

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the left-hand portion of Figure 10. During that introduction operation, the tongues 77 become resiliently deformed laterally towards the inner side until the enlargements 79 are positioned below the frustoconical portions 83 and the 5 shoulders 85 abut the upper surface of the anti-debris grid 31. The lower plugs 19 of the rods 3 are then assembled by being engaged with the upper grid 31.

Subsequently, the upper grid 31 is moved into abutment 10 against the lower unit 29 so that the projections 71 are introduced inside the rings 75. The projections 71 prevent deformation of the plates 77 and therefore the lower plugs 19 from being disengaged from the upper plate 31.

15 Fixing the bottom end-piece 7 to the guide tubes 11 by means of the screws 43 completes the construction of the support skeleton 5.

In that second variant, the lower ends of the fuel rods 3 20 are also secured longitudinally and laterally relative to the end-piece 7.

In the third variant of Figure 11, the lower plugs 19 of the fuel rods 3 comprise widened lower feet 89, for example, in 25 the form of discs having a diameter greater than the outer diameter of the external claddings 17.

After fitting the fuel rods 3, by means of the upper ends thereof, in the rings 51 of the grid 31, those feet 89 30 engage in lower countersinkings 91 which are provided in the rings 51. The feet 89, and therefore the lower ends of the fuel rods 3, are therefore secured longitudinally between the lower member 29 of the end-piece 7 and the upper plate

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31, by ~~means of~~ the screws 43 for fixing to the guide tubes
11.

In the variant of Figure 12, the lower plugs 19 of the fuel
5 rods 3 also comprise rings 75 which, however, are not split.
Those rings 75 have been introduced in the passages 52 of
the rings 51 and fixed to the rings 51 by expansion-rolling.

The lower ends of the fuel rods 3 are therefore secured
10 longitudinally and laterally to the upper plate 31 of the
bottom end-piece 7 which is itself fixed, by the screws 43,
to the member 29 of the bottom end-piece 7.

Figure 13 illustrates still another variant, in which the
15 securing of the fuel rods 3 to the end-piece 7 is brought
about by ~~means of~~ screws 43 similar to those used for fixing
to the guide tubes 11.

Thus, each nose 39 arranged below a rod 3 is formed by a
20 head 45 of a screw 43, whose shank 62 extends through the
corresponding unit 33 and which is screwed in the lower plug
19 of the corresponding rod 3.

In each of the embodiments and in each of the variants
25 described above, it is possible for the end-piece 7 not to
comprise an anti-debris filter.

It will again be appreciated that the presence, in the end-
piece 7, of a maintenance means, or more preferably
30 means arrangement or an arrangement for laterally and/or
longitudinally securing all the rods 3, may be envisaged
separately from the use of noses 39 for orientating the flow
of coolant water along the rods 3 because they independently

allow the risks of vibration of the fuel rods 3 to be limited.

In some variants, it is possible for some rods not to be
5 maintained by the end-piece 7, but the majority of the rods remain in a maintained state.

More generally, the principles described above may be used not only for assemblies which are intended for
10 ~~pressurised~~pressurized water reactors, but also for those intended for boiling water reactors (BWR) .

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ABSTRACT

This ~~An~~ end-piece comprises ~~means~~ an arrangement for
5 maintaining the adjacent longitudinal ends ~~(+19)~~ of
substantially all the fuel rods ~~(3)~~, which, wherein the
maintenance means ~~are~~arrangement is arranged at nodes of the
substantially regular network formed by the rods.